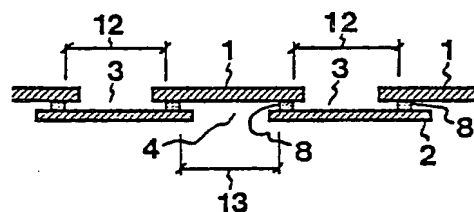
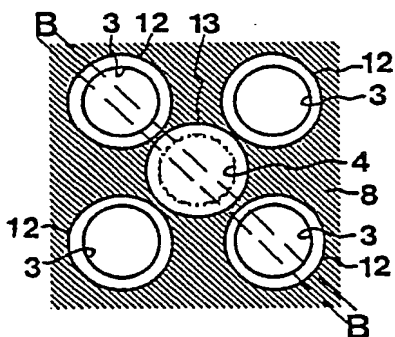




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(54) Title: MEMBRANE STRUCTURE AND METHOD FOR THE MANUFACTURE THEREOF



## (57) Abstract

The invention relates to a method of making a membrane structure having two parallel membranes (1, 2), both of which are provided with a multiplicity of perforations (3, 4), the perforations (3) in a first one of said membranes being disposed opposite to unperforated parts (5) of the second membrane (2), and a multiplicity of separate spacing means (6) arranged between said membranes (1, 2) and serving to maintain said membranes mutually spaced apart. A continuous spacing layer (8) of a material (or materials) other than that of the membranes (1, 2) and of a predetermined thickness corresponding to the said spacing, is provided between the membranes. The spacing layer (8) is successively removed via the perforations (3, 4) of at least one of said membranes, such that there are formed in the spacing layer of the finished structure exposed passages (7) between the perforations (3) in the first membrane (1) and the perforations (4) in the second membrane (2), and such that the remainder of the said spacing layer (8) forms the said spacing means (6). The invention also comprises a membrane structure made in accordance with this method.

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MEMBRANE STRUCTURE AND METHOD FOR THE MANUFACTURE THEREOF

The present invention comprises, in one of its aspects, a method of making a membrane structure having two parallel membranes, both of which are provided with a multiplicity of perforations, the perforations in a first one of said membranes being disposed opposite to unperforated parts of the second membrane, and a multiplicity of separate spacing means arranged between said membranes and serving to maintain said membranes mutually spaced apart. The invention also comprises a membrane structure made in accordance with this method.

In its basic design, a membrane structure made in accordance with the invention can be directly used as a particle filter, but if especial electric properties are chosen for the membrane structure, it may also be used for other purposes, for example flow control, particle detection, metering the amount of a substance, flow rate metering etc.

Before the special features of the invention are described in detail, there is cause for examining a prior art structure, even though the known structure in many respects is essentially different from the present invention. A membrane structure with two layers of mutually offset perforations is disclosed in GB Patent 840,615 filed on 13th October 1958 under the title "Filtering Septum and Method of making it". This structure is made of two metal foils, each having a thickness in the order of 0.20 mm, and the perforations have a diameter in the order of 1 mm and a centre-to-centre distance of about 2.5 mm, which thus gives about 16 perforations/cm<sup>2</sup>. During the manufacture of this known structure, the unperforated metal foils are first held in direct contact with one another as a unit. Then, the held-together metal foils are punched for simultaneously making a multiplicity of coincident perforations in both foils, whereby there is formed, at each punched perforation, a downwardly bent

circular flange having a serrated edge line and projecting from the foil. Then, the perforated foils are detached from one another and so mutually offset that the perforations of one foil are caused to lie opposite unperforated portions of the other foil. The downwardly bent flanges at the perforations of one foil maintain this foil at a distance from the other foil, and free passages from the perforations in one foil to the perforations of the other foil are obtained between the "serrations" of the downwardly bent flanges and the metal foil in contact with said serrations.

This known structure is intended to be used as a particle filter. A gas or a liquid to be filtered is conducted through the perforations of one foil, passes between the serrations of the flanges at the inflow point, flows between the foils in parallel therewith, passes again between the serrations of flanges at the outflow point and, finally, leaves the structure through the perforations in the other foil. The degree of filtration is determined by the size and shape of the free passages formed by the serrations.

The prior art structure according to GB 840,615 suffers from the following shortcomings:

1. The dimension of the free passages, i.e. the degree of filtration in this case, is determined by the size and shape of the deformations produced by the punching operation. As a result, the size and shape of these deformations cannot be controlled to any appreciable degree, i.e. the degree of filtration will not be well-defined. In actual practice, this also sets a lower limit to the possible dimensions of the free passages.
2. Since the structure is made from metal foils, and since the perforation are punched out, it is not possible, in actual practice, either to make the perforations much smaller than the said 1 mm or to place them closer than the said 2.5 mm. This is an unde-

sirable restriction considering the effect that these dimensions have on the flow resistance of the structure.

3. The metal foils are first punched and then relatively offset to be finally fixed in the offset position, which means an undesirable uncertainty regarding the offset position of the perforations, and also that special measures and/or means must be provided for fixing the offset metal foils.
4. Since the structure is made of metal, it cannot be used in any environment whatever; high temperatures, corrosive gases or liquids etc. may damage the structure and reduce its function.

In consideration of the prior art filter structure as described above, the method of making it, and its shortcomings, it is the object of the present invention to provide on the one hand a membrane structure of the type referred to in the introduction, which does not have the above-mentioned shortcomings 1-4 and, on the other hand, a method for the manufacture of such a structure.

To achieve these and other objects which will be stated in more detail hereinafter, the invention provides a method for the manufacture of a membrane structure of the type referred to above, a method which is characterised in that a continuous spacing layer of a material other than that of the membranes and of a predetermined thickness corresponding to the said spacing, is provided between the membranes, and that the spacing layer is successively removed via the perforations of at least one of said membranes, such that there are formed in the spacing layer of the finished structure exposed passages or channels between the perforations in the first membrane and the perforations in the second membrane, and such that the remainder of the said spacing layer forms the said separate spacing means.

Since the spacing means according to the invention are formed from an initially continuous spacing layer having the same thickness as the spacing means, the latter can be given exactly the same height because such a continuous spacing layer can be manufactured with far greater accuracy than separate individual spacing means. Another important feature of the manufacturing method according to the invention is that the spacing layer is made of a material different from that of the membranes. The reason for this is that it is desired to remove from the spacing layer the material which is not to be included in the finished structure. By selecting a different material (or several different materials) for the spacing layer (or several adjoining layers), it is possible, via the perforations in at least one of said membranes, to subject the initially continuous spacing layer to a treatment which successively removes the material of which the spacing layer is made, but which does not affect the material of which the membranes are made.

To be able to establish well-defined dimensions of the exposed channels, it is preferred not to terminate the successive removal of the spacing layer until the exposed channels have obtained a minimum width which is greater than the said spacing between the membranes. The size of the largest particles that can pass through the structure, if this is used as a particle filter, will then be determined by the said spacing between the membranes, i.e. by the thickness of the spacing layer.

In an especially preferred execution of the method according to the invention, the membranes need not be mutually offset after perforation. In particular, this execution of the method according to the invention makes it possible to use the perforations in one membrane in order to define the positions of the perforations in the other membrane.

To this end, a preferred execution of the method according to the invention is characterised by forming, in a first step, the perforations in the first membrane and, coincident with these perforations, perforations through the continuous spacing layer; subjecting, in a second step and via said coincident perforations, portions of the second membrane exposed towards these perforations to such a treatment that the second membrane at these exposed portions is reinforced prior to a third step, and forming, in said third step, the perforations in said second membrane by removing from the side of said second membrane facing away from said first membrane substantially only unreinforced portions of said second membrane, the two membranes and the spacing layer being held fixed relative to one another at least from said second step on. In a fourth step, it is then possible to form the separate spacing means by said successive removal of the spacing layer through the perforations in at least one of said membranes. It is also possible to remove the spacing layer, wholly or partly, at an earlier stage.

In a presently preferred embodiment, the membranes are made of silicon and the spacing layer of silica. The reinforcing treatment of the second step is carried out in the form of a diffusion process in which there is introduced, through the coincident perforations in the first membrane and the spacing layer, a dopant, such as boron, which, when combined with the dopable material, the silicon, of the second membrane, at the said exposed portions of the second membrane, reinforces these portions against a subsequent etching which is carried out in the said third step to remove undoped portions of said second membrane.

It is especially important that such diffusion is effected both in depth and laterally so that doped (i.e. reinforced) portions are obtained which extend laterally beyond the boundary lines of the exposed portions of the second membrane and in under the unperforated portions of

the first membrane and the spacing layer. In this manner, there is obtained, after removal of undoped portions of the second membrane, a continuous second membrane, and furthermore it is possible later on to obtain a membrane structure held together by the spacing means.

The invention also relates to a membrane structure which is of the type referred to into the introduction and which, according to the above-described method according to the invention, is characterised in that at least one of said membranes is made of a dopable material, that unperforated portions of the said one membrane are doped with a dopant, and that the spacing means are made of a different material than the membranes.

The dopable material of the said one membrane preferably is silicon, and the said dopant preferably is boron.

Furthermore, the spacing means preferably have a cohering effect on the membranes, in which case no further means are required for holding together and mutually fixing the membranes.

The separate spacing means are preferably so positioned relative to the perforations of the membranes that free passages are formed from the perforations in the first membrane, between adjoining spacing means and out through the perforations in the second membrane, which should be compared with the free passages between the "serrations" of one and the same flange in GB 840,615.

Further features, advantages and applications of the invention will now be described hereinafter, on the one hand in the form of an exemplifying embodiment of the membrane structure according to the invention and, on the other hand, in the form of an exemplifying method of making the membrane structure, reference being had to the accompanying drawings.

Fig. 1 is a fundamental, highly simplified top plan view of a membrane structure according to the invention.

Figs. 2A and 2B are cross-sectional views of broken-out portions between double lines A-A and B-B, respectively, in Fig. 1.

5 Figs. 3A-3D illustrate schematically successive steps in the manufacture of a perforated membrane structure according to the invention.

10 Figs. 4A and 4B are, respectively, a schematic top plan view and a sectional view between double lines B-B in Fig. 4A, of an intermediate stage in the manufacture of separate spacing means.

Figs 5A and 5B are, respectively, a schematic top plan view and a sectional view between double lines B-B in Fig. 5A, of a final stage in the manufacture of separate spacing means.

15 Fig. 6 is a schematic top plan view of a perforated membrane structure manufactured according to the principles shown in Figs. 3A-3D, 4A and 4B, and Figs. 5A and 5B.

20 Figs. 7A and 7B are cross-sectional views of broken-out portions between double lines A-A and B-B, respectively, in Fig. 6.

Fig. 8 is a broken-out schematic view from below of a finished structure comprising a perforated membrane and a frame.

25 Fig. 9 is a cross-sectional view on a larger scale of the structure shown in Fig. 8, taken along line IX-IX in Fig. 8.

30 Figs. 10A and 10B are the same cross-sectional views as in Figs. 7A and 7B, respectively, and illustrate a method of bending a perforated membrane structure according to the invention.

35 Figs. 11A and 11B are the same cross-sectional views as in Figs. 7A and 7B, respectively, and illustrate a different method of bending a perforated membrane structure according to the invention.

BASIC CONSTRUCTION: The structure as shown in Figs. 1, 2A and 2B comprises two parallel silicon membranes 1 and 2 each having a multiplicity of perforations 3 and 4, respectively. The perforations have a diameter of about 10  $\mu\text{m}$  and are arranged, in the respective membrane, in a checked pattern with a centre-to-centre distance of about 20  $\mu\text{m}$ , which gives about 250000 perforations/ $\text{cm}^2$  in each membrane. In Fig. 1, the perforations 3 of the upper membrane 1 are shown as full circles, while the perforations 4 of the lower membrane are shown as broken circles. It thus appears from Fig. 1 that the two "checked patterns" are so mutually offset that the perforations 3 in the upper membrane 1 lie opposite to unperforated portions 5 of the second membrane 2, as will appear also from Figs. 2A and 2B.

The membranes 1 and 2 are held mutually spaced apart at a distance of, for example, 0.01-1  $\mu\text{m}$  by a multiplicity of separate spacing means 6. In accordance with the invention, these spacing means are made of a different material than the membranes 1 and 2, in this case silica. The spacing means 6 are positioned such between the perforations 3, 4 of the membranes that free passages or channels 7 are formed between adjoining spacing means 6, and this means in other words that a gas or a liquid, as shown by the arrows in Fig. 2B, can flow in through the perforations in the one membrane, through the passages 7 and out through the perforations in the other membrane.

It should here be emphasised that, if the distance between adjoining spacing means 6 is made greater than the distance between the membranes, as in the above-described embodiment, the flow through the passages 7 is substantially restricted by the height of the spacing means 6, i.e. the mutual distance between the membranes 1 and 2. This is not the case in the construction according to, for example, GB 840,615.

The spacing means 6 here also have a cohering effect on the membranes 1 and 2 so that no other means are required for this purpose.

5 The two membranes 1 and 2 and the intermediate spacing means 6 are mounted on a frame which imparts a sufficient mechanical strength to the structure. The frame is preferably integrated into the lower membrane and will be described in detail hereinafter.

10 PARTICLE FILTER: After this description of the basic construction of a membrane structure according to the invention, it will be appreciated that the structure can be used as a highly efficient particle filter. The degree of filtration, i.e. the size of the particles filtered off from a flow (Fig. 2B) through the structure, is determined  
15 by the spacing between the membranes 1, 2, which in turn is determined by the thickness or height of the spacing means 6. A membrane spacing suitable from the viewpoint of production is 0.01-1  $\mu\text{m}$  as mentioned above. By using the production technique described hereinafter, the spacing  
20 means 6 according to the invention can be manufactured from an initially continuous spacing layer between the membranes, and this in turn means that this filtration technique where the degree of filtration is determined by a layer thickness (the spacing means) instead of by a photolithographic process, is advantageous in so far as it is  
25 much easier to manufacture a submicron layer of silica with high accuracy than perforations of the same size by using photolithography.

MANUFACTURE: A method according to the invention for  
30 manufacturing a membrane structure, the fundamental appearance of which has been explained above with reference to Figs. 1 and 2, 2B, is described hereinafter.

The manufacture of the membrane structure is mainly based on conventional semiconductor technique and on a  
35 self-registering two-step process for (I) registering the perforations and (II) for determining the position and shape of the spacing means. By this special two-step pro-

cess, it is possible by means of a single perforation pattern, and without offsetting perforated membranes relative to one another, to define in a first step (I) the mutual positions of the perforations 3 and 4 in the membranes and, in a second step (II), the positions of the separate spacing means 6 between the membranes.

The starting material (Fig. 3A) is a silicon wafer (for example monocrystalline silicon) which has a thickness of, for example, 0.2-0.4 mm and which is to form the second membrane 2 and the said frame. On this silicon wafer 2, a layer 8 of a different material, such as silica, having a thickness of about 0.1-1  $\mu\text{m}$  is deposited. The layer 8 constitutes the above-mentioned spacing layer and will subsequently be formed into the separate spacing means 6. (In a variant not shown in the drawings, the spacing means 6 may also be formed of several superimposed subspacing layers, optionally made of mutually different materials.) Then, a layer of silicon (polycrystalline silicon) is deposited on top of the spacing layer 8 to form the first perforated membrane 1, and then a protective layer 9, for example in the form of a silica layer, is deposited on top of the silicon layer 1.

After that, coincident perforations 3 are formed by photolithography (Fig. 3B) in the layers 9, 1 and 8. The perforations in the spacing layers 8 are made by silica etching which does not affect the underlying silicon wafer 2. The perforations 3 in the first membrane are now ready.

In the next step (Fig. 3C) a dopant, boron, in high concentration is introduced through the perforations 3. More particularly, the exposed surface portions of the silicon wafer 2 are subjected to a high concentration of boron in the gaseous phase at a temperature which, in connection with semiconductors, is extremely high, for example 1200°C. As a result, all boron will diffuse into the portions 5, both in depth and laterally. More particularly, the lateral diffusion results in the formation of

doped areas also underneath the unperforated portions of the uppermost silicon layer 1 and the spacing layer 8. The undoped areas 10 of the silicon wafer 2 are intended later on to form the perforations 4 in the lower membrane 2.

5       The lower silicon wafer 2 is doped with boron because a high concentration of boron in silicon greatly reduces (for example by a factor 1000) the etching rate in silicon for certain types of silicon etching. The degree of doping may vary from case to case, but generally the doping is  
10 far stronger than the n- and p-doping traditionally carried out in the production of electronic semiconductor components.

      Since an intense doping of silicon with boron may also result in a reduced strength or crack formations in  
15 the silicon, it was found preferable to form the said protective layer 9 on top of the upper silicon layer 1 in order not to reduce the mechanical strength thereof by an excessive boron doping. Some boron doping of the upper membrane 1 may, however, be desirable. If the structure is  
20 to be used for applications requiring electrically conductive properties of the membranes, boron doping will contribute to a desired increased conductivity. The degree of doping will, of course, depend also on the thickness of the protective layer 9.

25       It should also be noted that, in Figs. 3B and 3C, the separate spacing means 6 have as yet not been finished.

      The boron doping step of Fig. 3C is followed by a second silicon etching during which the silicon wafer 2 is etched from below through a frame-defining mask (Fig. 3D).  
30 Since the silicon etching rate is reduced to practically zero by excessively high boron doping concentrations ("boron etch-stop"), the areas 5 remain unaffected by this silicon etching, whereas the undoped areas 10 in the silicon sheet 2 are removed by this etching. By using a frame-defining mask  
35 on the "rear face" of the silicon wafer 2, there is obtained, by this silicon etching, also a frame 11 integrated with the second membrane 2 and shown in Figs. 8 and 9.

After the second silicon etching, the structure will have the appearance shown in Fig. 3D in which the positions of the perforations 4 in the second membrane 2 are defined on the basis of the positions of the perforations 3 in the first membrane 1. This means that the membranes 1 and 2 need never be relatively offset after they have been perforated, and that the two "checked patterns" of the perforations 3 and 4, respectively, will be exactly offset relative to one another. In other words, the perforations 4 will always lie exactly midway between the perforations 3.

It is also noted that the spacing layer 8 is still so intact in Fig. 3D that there are as yet no free passages between the perforations 3 and 4.

After the perforations 3 in the membrane 1 and the perforations 4 in the membrane 2 have been formed, it only remains to form the separate spacing means 6. This procedure will now be described with reference to Figs. 4A, 4B and Figs. 5A, 5B.

The separate spacing means 6 are formed by successively removing, by liquid etching, the silica 8 accessible through the perforations 3 and 4. In the embodiment shown in Figs. 4 and 5, both sides of the structure are subjected to liquid etching, but it is also possible to etch from one side only. In Fig. 4A, the spacing layer 8 has been etched for some time, and etching is still going on. In the lateral sense, etching has progressed to an "etching limit" which, in Fig. 4A, is shown by circles 12 for the etching which is done through the perforations 3, and by circles 13 for the etching which is done through the perforations 4. As will appear from Fig. 4B which is a broken-out section between the double lines B-B in Fig. 4A, the circles 12 and 13 have not yet met, which means that the spacing layer 8 still is a continuous unit, without forming any free passages through the structure.

The etching of the spacing layer 8 is discontinued when the circles 12, 13 in Fig. 4A meet, i.e. when the two etching areas meet. Free passages 7 (cf. Fig. 2B) have

thus been formed between the remainder of the spacing layer 8, which now forms the separate spacing means 6. A free flow path through the membranes has been established, as shown by the arrows in Figs. 5A and 5B, and at the same time the spacing means 6 maintain the membranes 1 and 2 at a constant and exactly predetermined mutual distance.

Fig. 6 and Figs. 7A and 7B illustrate a more realistic appearance of the finished structure, as compared with the fundamental structure previously illustrated in Fig. 1 and in Figs. 2A and 2B. As will appear from Fig. 6, the perforations 4 in the second membrane 2 will not be entirely circular, but rather in the form of squares. The reason for this is that each such perforation 4 is surrounded by four symmetrically distributed doping areas 5. Fig. 7A which is a broken-out section between the double lines A-A in Fig. 6, clearly shows how the second membrane 2 is built up of doped areas 5 which overlap one another and are held together in the areas 14 underneath the spacing means 6.

It should here be mentioned that the perforations 4 in the second membrane 2 can be produced also in other ways. One variant is to diffuse phosphorus through the perforations 3 of the first membrane 1 and to allow the phosphorus to penetrate into a boron-doped crystalline silicon sheet 2. By a special silicon etching and a voltage applied between the etching liquid and the silicon disk 2, the boron-doped silicon accessible through the rear face mask is etched, whereas the phosphorus-doped area is left intact. The final structure will have essentially the same appearance as has been described above.

#### Practical Applications

The membrane structure according to the invention and the method of making it have now been described in a preferred form. Even though the inventive idea as defined by the appended claims is not dependent on the field of application of the invention, mention may be made of some

specific applications. The use of the membrane structure as a particle filter has already been described.

5 A further conceivable application is using the membrane structure as a valve for controlling a gas or liquid flow through the structure. For such application, the structure is formed such that one perforated membrane 1 can be bent towards the other perforated membrane 2 to control the size of the free passages 7. The downward bend of the membrane required for the flow control can be  
10 achieved for example in the manner shown Figs. 10A and 10B. In these Figures, the two perforated membranes 1 and 2 are made of an electrically conductive material, such as boron-doped silicon, whereas the spacing material is electrically nonconductive, and an electric voltage (of the  
15 order 5-10 V) is applied across the membranes 1 and 2. As a result, an electrostatic force is established between the membranes 1 and 2, whereby the membranes are attracted to throttle the flow to an extent corresponding to the magnitude of the voltage applied.

20 A different way of achieving the said downward-bend is to make for example the first perforated membrane 1 from two layers 1a and 1b of different materials with different coefficients of thermal expansion, the two layers being so mutually arranged that the first membrane 1 is  
25 bent towards the second membrane 2, for example by heating. To heat the membranes, an electric current can be conducted through one or both membranes 1 and 2.

The structure disclosed herein may also be used as a detector for charged particles. If a fluid is conducted in  
30 between the two perforated membranes 1 and 2, there is obtainable, by continuously measuring the capacitance between the membranes 1 and 2, a measure of the quantity of electrically charged or polar particles passing through the structure. This measuring procedure thus makes it possible  
35 to measure the dielectricity constant.

A further conceivable application of the membrane structure is the determination of a substance and concentration measurement. The two membranes 1 and 2 are so close to one another that it is possible, by means of an external voltage applied across the two membranes, to  
5 create sufficiently high electric fields to ionise or otherwise produce electrically charged particles. The requisite voltage depends upon the substance passing through the structure. To detect the electrically charged particles,  
10 the electric capacitance between the membranes 1, 2 is measured, simultaneously as the said voltage is supplied thereto. This measuring technique is based on the hypothesis that a substance passing through the structure has a minimum voltage at which electrically charged particles  
15 are formed. By recording the voltage at which a significant change of the capacitance occurs, one can determine the substance passing between the membranes 1, 2. At the same time, the change of the capacitance will be a measure of the concentration of the substance.

20 Still another conceivable application of the membrane structure according to the invention is that of a flow sensor. Instead of applying a constant voltage across the membrane, as has been described above, voltage pulses can be applied across the two perforated membranes. If the  
25 voltage pulses are sufficiently strong, which can be obtained for example by superposition of a constant voltage, electric charges can be produced which then are detectable by capacitance measurement. The higher the gas or liquid flow through the structure, the quicker will the change in  
30 capacitance induced by each voltage pulse return to the initial capacitance value when the electric charges produced pass through and out of the structure. The capacitance change per unit of time will then be a measure of the flow rate through the structure. The maximum capacitance change and the time it takes to reestablish the ca-  
35 pacitance after each voltage pulse can be utilised for determining the flow rate and the amount of the substance

passing through the structure. By electric feed-back, an output signal is obtainable, the frequency of which is related to one of the parameters flow volume or flow rate.

Because the presently preferred embodiment of the  
5 membrane structure is made of silicon and silica, the structure is capable of withstanding extremely high temperatures, over 1000°C, and aggressive environmental conditions, such as acids and solvents. This is a great advantage both in the active use of the structure and the  
10 cleaning thereof.

As has been mentioned above under the sub-title MANUFACTURE, it is also possible to effect the successive removal of spacing material through the perforations 3 of the first membrane 1 only. In a variant of the above-mentioned production technique, the entire successive removal  
15 of spacing material is carried out before the perforations 4 are made in the second membrane 2. In such a variant, spacing material is removed some way into the areas where the perforations 4 in the second membrane 2 are to be  
20 formed later on. When the perforations 4 are then formed, certain parts of the remaining spacing material will be exposed at these locations. These exposed parts of the spacing layer do not function as spacing means between the membranes because they are in contact with one membrane  
25 only. On the other hand, these exposed remaining parts of the spacing material will bind together the separate spacing means 6 which are in contact with the both membranes. The expression "separate distance means" should therefore be interpreted throughout in the sense that the  
30 remaining parts of the spacing material which are in contact with both membranes, i.e. the spacing means 6, are not in direct contact with one another. However, the word "separate" comprises, according to the invention, the variant in which the "separate spacing means" can be in  
35 contact with one another via the remaining spacing material not serving as spacing means.

## CLAIMS

1. A method of making a membrane structure having two  
5 parallel membranes (1, 2), both of which are provided with  
a multiplicity of perforations (3, 4), the perforations  
(3) in a first one of said membranes being disposed oppo-  
site to unperforated parts (5) of the second membrane (2),  
and a multiplicity of separate spacing means (6) arranged  
10 between said membranes (1, 2) and serving to maintain said  
membranes mutually spaced apart, c h a r a c t e r -  
i s e d in that a continuous spacing layer (8) of a mate-  
rial (or materials) other than that of the membranes (1,  
2) and of a predetermined thickness corresponding to the  
15 said spacing, is provided between the membranes, and that  
the spacing layer (8) is successively removed via the per-  
forations (3, 4) of at least one of said membranes, such  
that there are formed in the spacing layer (8) of the fi-  
nished structure exposed passages (7) between the perfora-  
20 tions (3) in the first membrane (1) and the perforations  
(4) in the second membrane (2), and such that the remain-  
der of the said spacing layer (8) forms the said spacing  
means (6).

2. A method as claimed in claim 1, c h a r a c -  
25 t e r i s e d in that the exposed passages (7) are given  
a minimum width which is greater than the said spacing  
between the membranes.

3. A method as claimed in claim 1 or 2, c h a -  
r a c t e r i s e d by forming, in a first step  
30 (Fig. 3B), the perforations (3) in the first membrane (1)  
and, coincident with these perforations, perforations  
through the continuous spacing layer (8); subjecting, in a  
second step (Fig. 3C) and via said coincident perforations  
(3), portions (5) of the second membrane (2) exposed to-  
35 wards these perforations to such a treatment that the se-  
cond membrane (2) at these exposed portions (5) is rein-  
forced prior to a third step (Fig. 3D), and forming, in

said third step, the perforations (4) in said second membrane (2) by removing from the side of said second membrane (2) facing away from said first membrane (1) substantially only unreinforced portions (10) of said second  
5 membrane (2), the two membranes (1, 2) and the spacing layer (8) being held fixed relative to one another at least from said second step on.

4. A method as claimed in claim 3, c h a r a c -  
t e r i s e d by forming, as a fourth step (Figs. 4 and  
10 5), the separate spacing means (6) by said successive removal of the spacing layer (8).

5. A method as claimed in claim 3 or 4, c h a -  
r a c t e r i s e d in that said second membrane is made of dopable material (Si), that the reinforcing treatment  
15 carried out in the second step comprises subjecting, via the coincident perforations (3), surface portions of said second membrane (2) exposed toward these perforations, to a dopant (B) which, when combined with the dopable material of the second membrane (2), reinforces the latter  
20 against a subsequent etching, whereby a diffusion in depth and in the lateral sense is achieved in portions (5) of said second membrane (2) at the said exposed surface portions, and that the forming of the perforations (4) in the second membrane (2), which is carried out in the said  
25 third step, comprises removing by the said etching undoped portions (10) of said second membrane (2).

6. A method as claimed in any one of claims 1-5, c h a r a c t e r i s e d in that one or both membranes (1, 2) are made of silicon.

30 7. A method as claimed in any one of claims 1-6, c h a r a c t e r i s e d in that the spacing layer (8) and the spacing means (6) are made of silica.

8. A membrane structure comprising two parallel membranes (1, 2), both of which are provided with a multi-  
35 plicity of perforations (3, 4), the perforations (3) in a first one of said membranes (1) being disposed opposite to unperforated parts (5) of the second membrane (2), and a

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multiplicity of separate spacing means (6) arranged between said membranes (1, 2) and serving to maintain said membranes mutually spaced apart, c h a r a c t e r -  
i s e d in that at least one of said membranes (2) is  
5 made of a dopable material, that unperforated portions (5) of the said one membrane (2) doped with a dopant, and that the spacing means (8) are made of a different material than the membranes (1, 2)

9. A membrane structure as claimed in claim 8,  
10 c h a r a c t e r i s e d in that the dopable material in said one membrane (2) is silicon.

10. A membrane structure as claimed in claim 8 or 9,  
c h a r a c t e r i s e d in that the said dopant is boron.

15 11. A membrane structure as claimed in any one claims 8-11, c h a r a c t e r i s e d in that the spacing means (6) have a cohering effect on the membranes (1, 2).

12. A membrane structure as claimed in any one of claims 8-11, c h a r a c t e r i s e d in that the separate spacing means (6) are so positioned relative to the perforations (3, 4) of the membranes that free passages (7) are formed from the perforations (3) in the first membrane (1), between adjoining spacing means (6) and out  
20 through the perforations (4) in the second membrane (2).

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FIG. 1

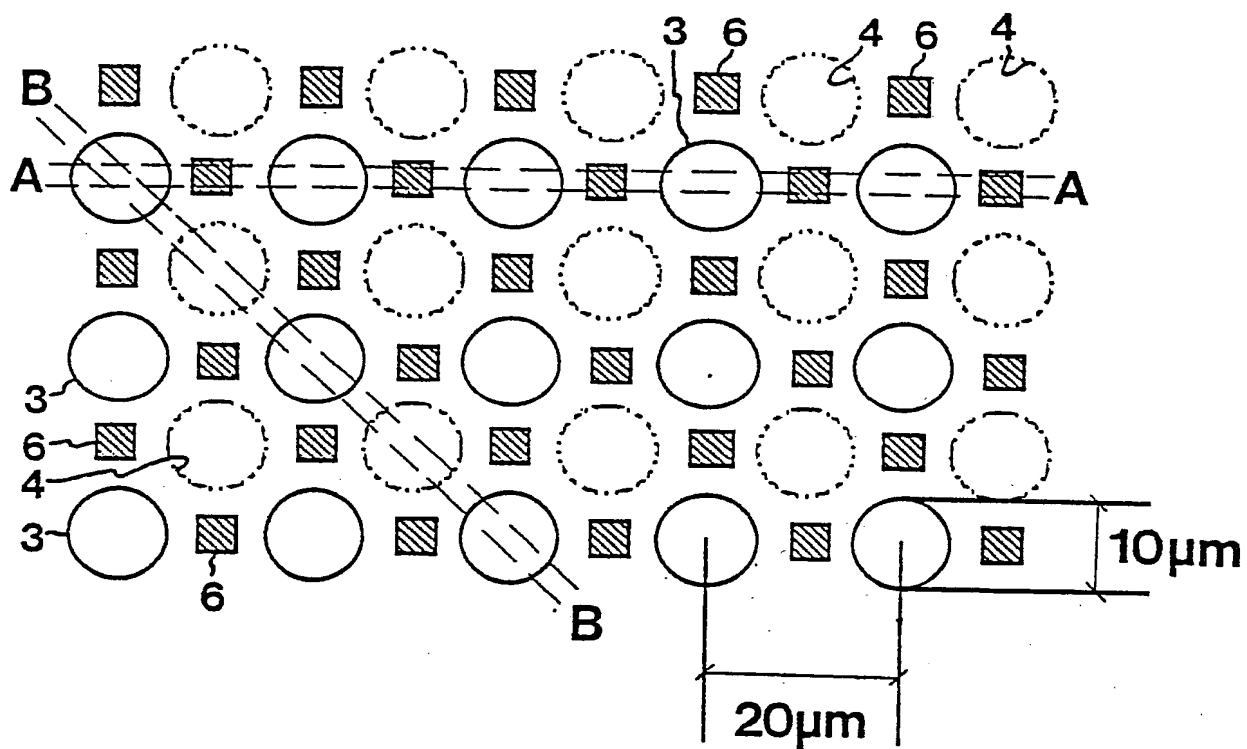


FIG. 2A

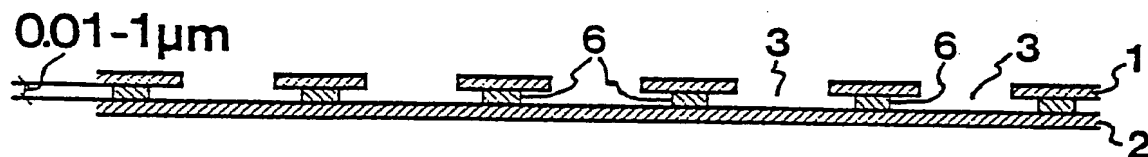
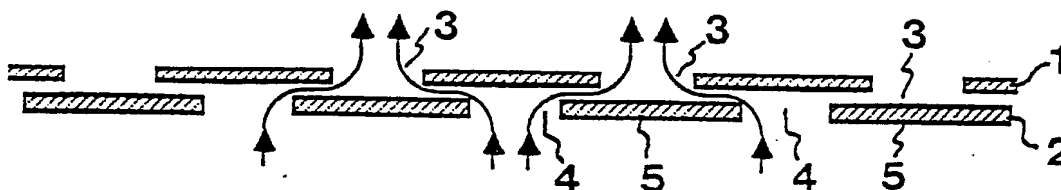


FIG. 2B



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FIG.3B

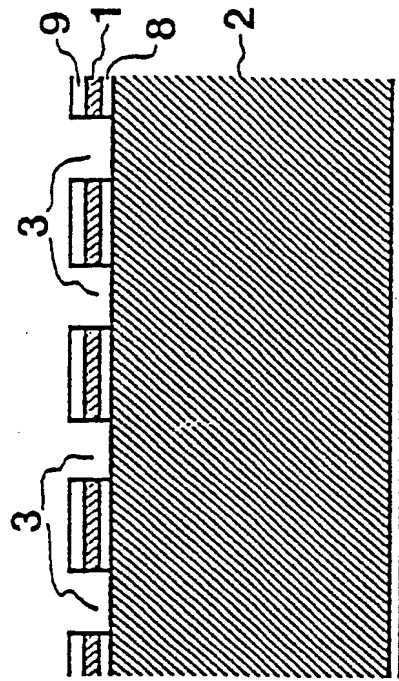


FIG.3D

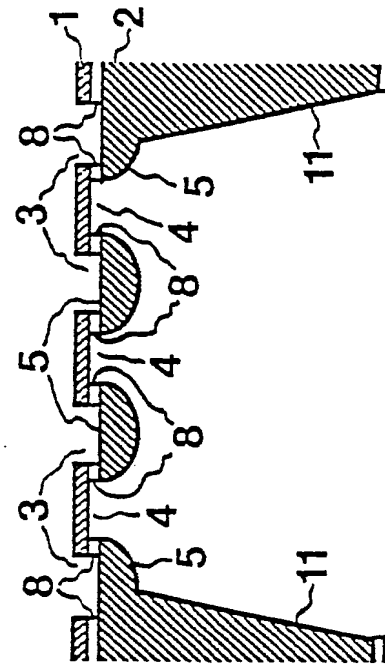


FIG.3A

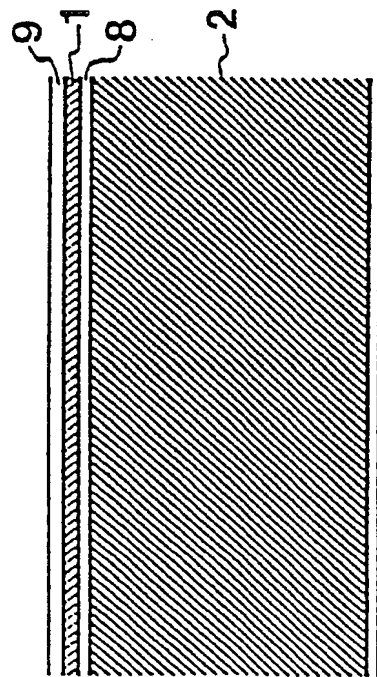
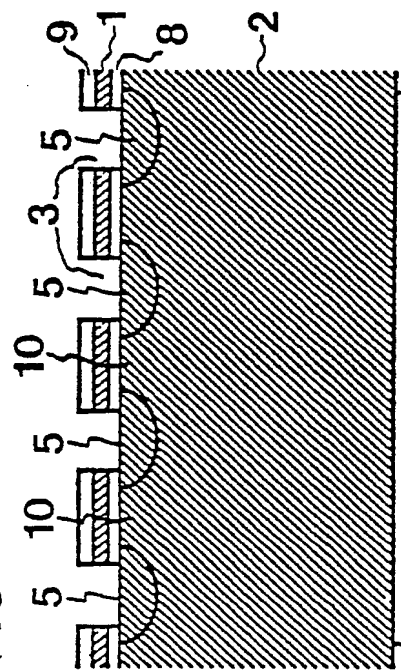


FIG.3C



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FIG. 5A

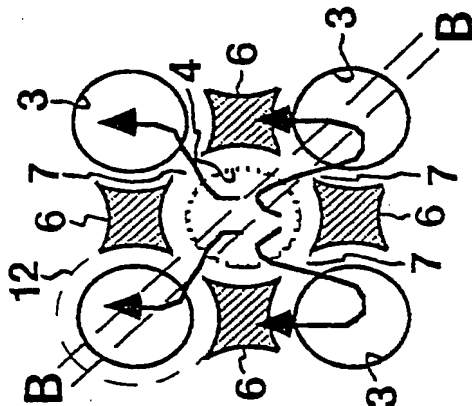


FIG. 4A

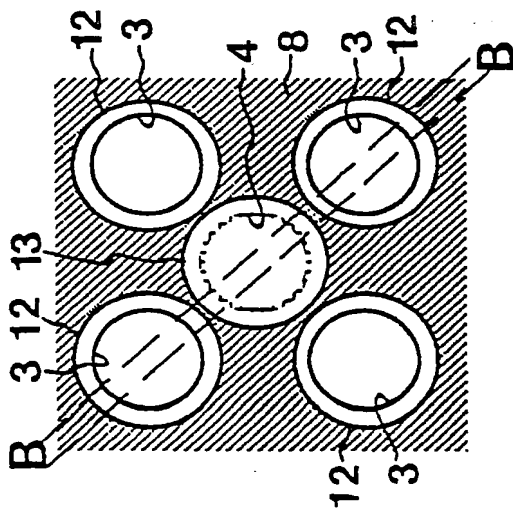


FIG. 5B

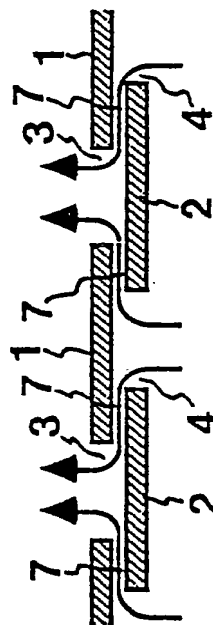
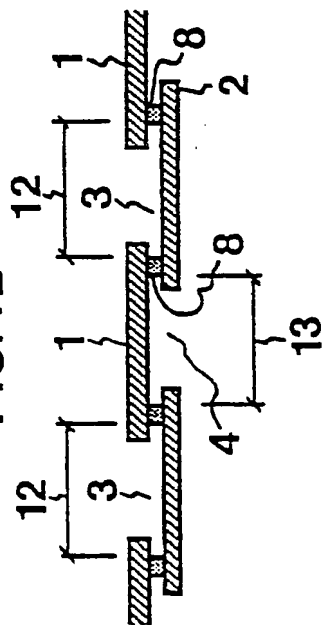


FIG. 4B



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FIG. 6

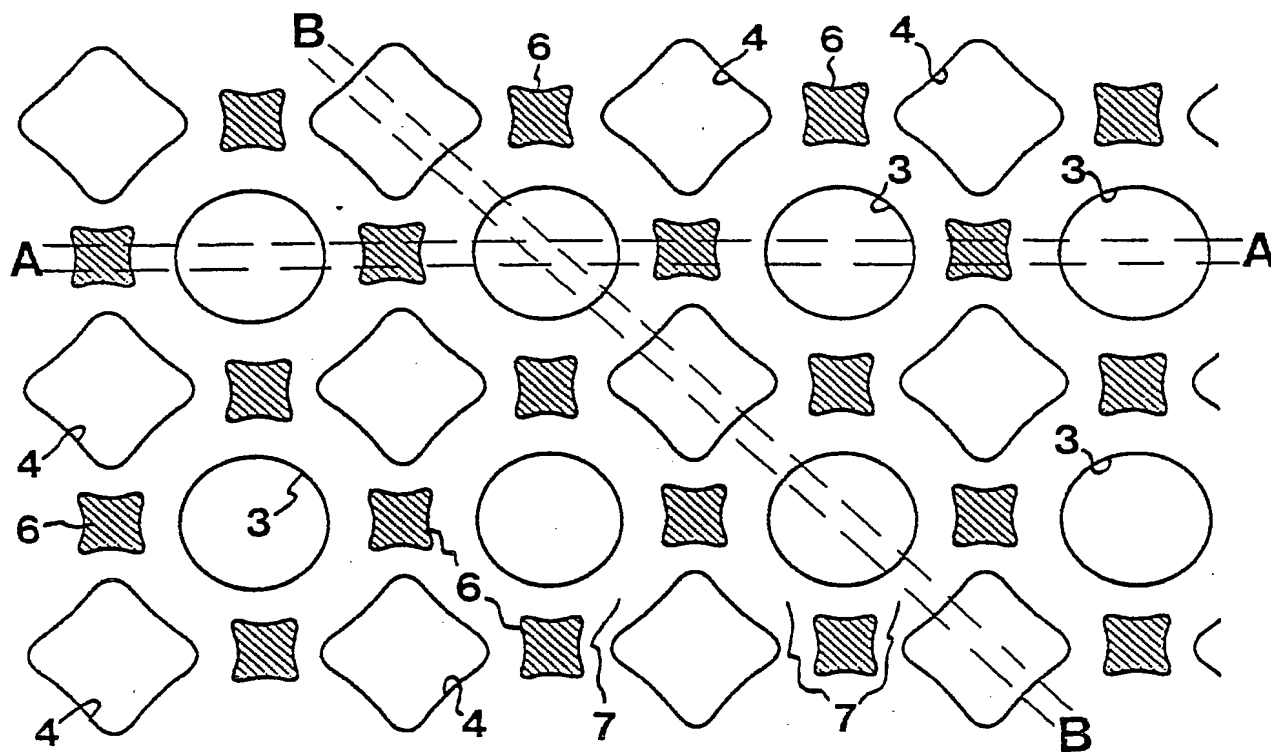


FIG. 7A

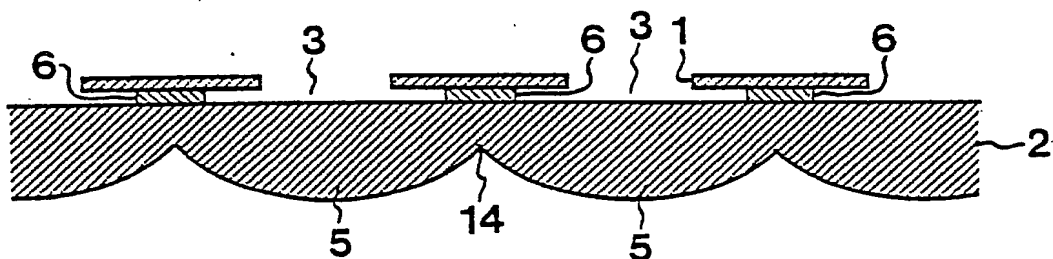
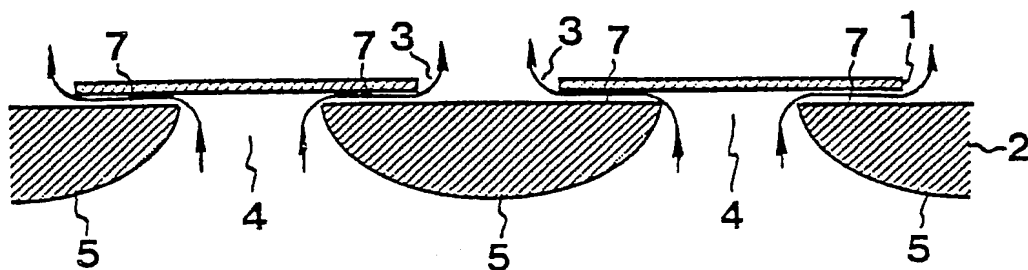
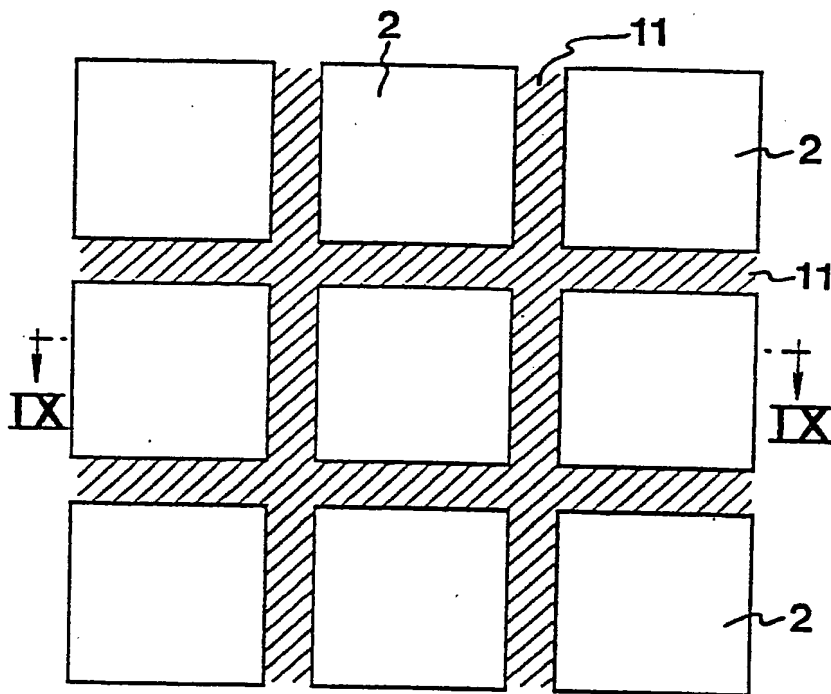


FIG. 7B

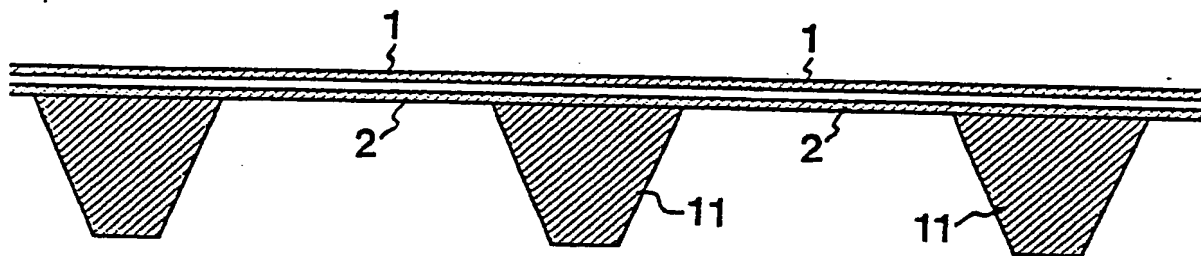


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**FIG. 8**



**FIG.9**



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FIG. 10A

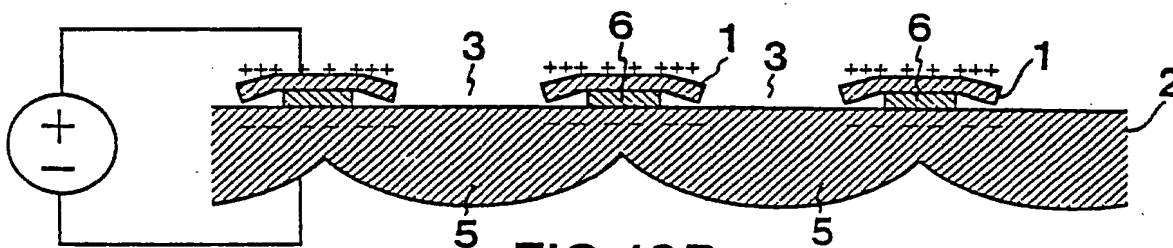


FIG. 10B

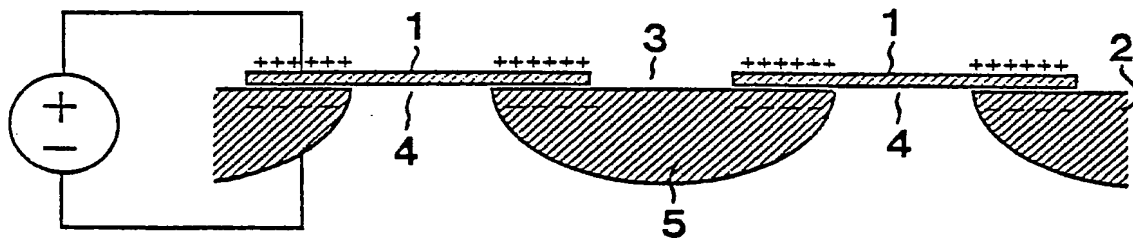


FIG. 11A

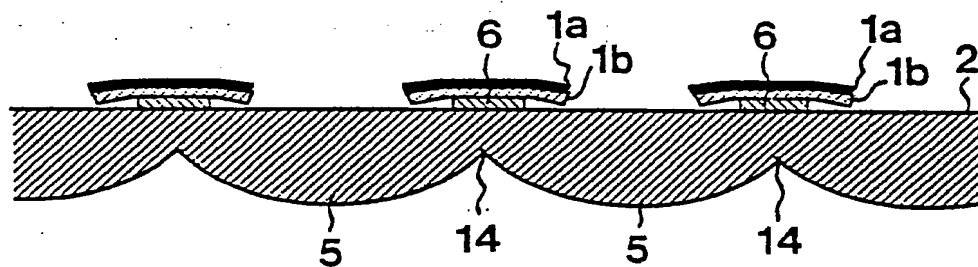
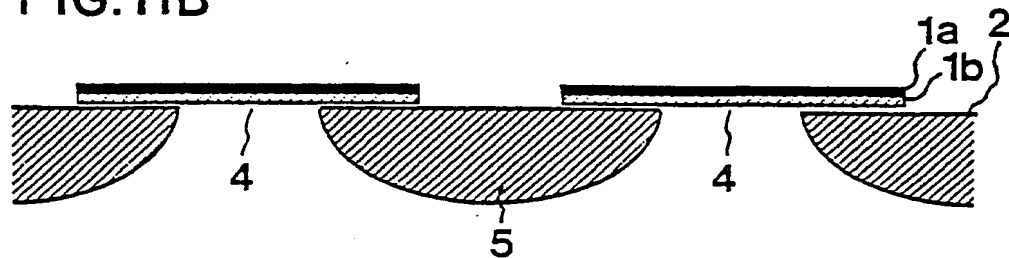


FIG. 11B



# INTERNATIONAL SEARCH REPORT

International Application No PCT/SE89/00124

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC 4		
B 01 D 13/04, 39/00, B 32 B 3/24, 31/14		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System :	Classification Symbols	
IPC 4	B 01 D 13/04, 39/00, /20; B 32 B 3/24, 31/14; F 16 K 1/12; G 01 F 1/56, /76, /86; G 01 P 5/08; G 01 R 27/26; H 01 G 1/005- /015 .../...	
Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched <sup>8</sup>		
SE, NO, DK, FI classes as above		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup></b>		
Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
A	GB, A, 1 487 741 (FACET ENTERPRISES INC) 5 October 1977	
A	US, A, 4 510 436 (RAYMOND) 9 April 1985	
A	GB, A, 840 615 (MULTI-METAL WIRE CLOTH CO INC.) 13 October 1958	
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>* Special categories of cited documents: <sup>14</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"F" document member of the same patent family</p> </div> </div>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search		Date of Mailing of this International Search Report
1989-05-26		1989-05-04
International Searching Authority		Signature of Authorized Officer
Swedish Patent Office		<i>J. Any</i> Johan Any

Form PCT/ISA/210 (second sheet) (January 1985)

## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

II

Fields Searched (cont)US C1 324: 11.4, 464, 466, 61R, 61P;73 : 521210: 500V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE <sup>1</sup>

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers ..... because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claim numbers ..... because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claim numbers ..... because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING <sup>2</sup>

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

## Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.